

December 7, 1964

Dr. George Jacobs
Code 5B
NASA Headquarters
Washington, D. C. 20546

Ref: NASw-1066 - "General Dynamics of Physical Chemical Systems in Mammals". First Quarterly Progress Report, December 7, 1964

Dear Dr. Jacobs:

In accordance with the requirements of the referenced contract, we are submitting this report for the first quarter - August 20 to November 20, 1964. Also included is the period June 1 to August 20, 1964 as authorized in Article XV of the contract, entitled "Date of Incurrence of Cost".

I - Summary of Work Performed

A Technical report was prepared and submitted to the Bioscience Programs Office, September 1, 1964. It contained results of studies on human thermoregulation, the cardiovascular system, the hormonal system, and the behavioral system. A new definition of life has been developed based on ideas of limit cycle engine oscillator operating characteristics of these living systems.

1. The content of the work on human thermoregulation was given as a talk in November 1964. It is summarized in the attached abstract of the paper read at the 17th Annual Conference of Medicine and Biology held in Cleveland, November 1964.

2. The modelling of the cardiovascular system has proceeded to a satisfactory explanation of the damping in the arterial system and a physical-mathematical theory for arterial branching.

3. The studies of the hormonal system has concentrated on cyclic mechanisms of interest in temperature and water regulation. The paper on human temperature regulation contains brief discussion of two hormones mechanisms. In addition, the September report postulated a thyroid involvement in water balance on a longer time basis. A mechanism for blood glucose regulation based on a 30 second cycle found by Anderson et al (1956) and involvement of insulin has been suggested.

4. The discussion of the behavioral system was continued with especial reference to applying the dynamic oscillator concepts to explanation of behavior and its possible mechanisms.

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5. A second technical report is in progress. It is continuing the studies in the four major system areas. The section on the behavior system will begin a preliminary survey of neuroanatomy and physiology with the object of ultimately attempting to bring the anatomy and behavior into a single unified model. Experimental work in the hormonal and behavior system is being planned to test the theoretical models.

6. A more vigorously complete mathematical analysis of the pressure-flow relations in the cardiovascular system is continuing. It is not likely that there will be any changes in the conclusions arrived at in the cruder treatment reported on in the September technical report. This work lays a foundation for analysis of normal and abnormal operational characteristics of the cardiovascular system and should be of interest ultimately in diagnosis and monitoring.

7. When complete, it is planned to submit a paper on the cardiovascular system analysis to the Project Officer for approval for presentation. A paper is also being prepared from the material covered in the talk on human temperature regulation.

8. The oscillator concepts discussed and developed in this program have led us to the conclusion that an instrument valuable in medical diagnosis and physiological research could be developed based on the spectral analysis of cyclic phenomena in mammals. With verbal permission of the Project Officer, a preliminary proposal for development of such an instrument has been submitted to the medicine and biology branch of the Atomic Energy Commission.

9. The review which served as the introductory report in the prior programs (NASw-678) has been published in the Annals of the New York Academy of Sciences, Vol 117, Article 1, pages 445-515, September 10, 1964.

II - Principal Investigator

The principal investigator is our chief Physicist A. S. Iberall. In this report period, he has devoted 358 hours to this project.

III - Trips to Scientific Meetings

1. Joint Automatic Control Conference, Stanford University, June 24-26, 1964.

In part of a continuing effort to keep abreast of what is new in control theory or in the physical and engineering point of view, A. S. Iberall attended the 1964 JAC Conference. This applies directly to the present program, since an important object of this program is to apply the physical concepts of control to biological systems analysis. Among important subjects discussed at the meeting were one following; Adaptive control; optimal control; systems design and analysis; and multivariable and multilevel systems.

2 European Trip Report

The principal investigator, A. Iberall, used the opportunity of attendance at an ONR sponsored European conference in Norway on hydrodynamics to discuss and investigate a number of problems of quite immediate interest to this current biophysics report. These items are touched on chronologically.

1. IMEKO Conference, Stockholm, September 14-18, originally an Iron Curtain country sponsored conference on instrumentation, it has sought to develop the prestige of IUTAM, and other similar international groups. Previous meetings were held in Budapest in 1958 and 1961. By this third meeting they have succeeded in involving Swedish, British, Italian, Japanese and some cooperation from American Automatic Control Council to which Iberall is a delegate, and its international parent body, International Federation of Automatic Control). The Iron Curtain country participation is Hungarian, Bulgarian, Czech, Polish, Romanian, Russian, German and Chinese. Individual representatives also were present from many other countries. The purpose of attending was to note this degree to which biological measurements received attention in such an international measurements meeting, to note any measurements or instruments suitable for biophysical measurements, to note any discussion arising on man in space programs. A capsule judgement is that the group is still essentially Hungarian dominated, that it is a light-weight group, that both Eastern and Western countries are very cautious in their desire to become anything more than casually involved in IMEKO.

2. C. von Euler, Karolinska Institute, Stockholm. Progress in thermoregulation, and ventilation dynamics was discussed. Our latest oxygen choke adrenaline muscle engine cycle was received with great interest.

3. I. Porja, St. Eriks Hospital, Stockholm. Arterial hemodynamics was discussed and the status of modelling of the arterial pulse was discussed. Considerable interest in seeing our latest work in this area was expressed.

4. J. Defares, Univ. of Leiden, Netherlands. He was out of the country, but his recent work in preliminary syntheses of the cardiovascular system was discussed with his coworkers.

5. A. Nordergraaf, Utrecht, Netherlands. Respective work in the arterial system was discussed and compared.

6. L. van der Tweel, Univ. of Amsterdam, Netherlands; McCulloch, MIT. The most recent work carried out in the September 1964 report was presented and defended to this most interested audience. A very lively discussion, and sympathetic acceptance was achieved. The work on the arterial pulse underwent considerable questioning.

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7. A. Remond, Hospital Salepatriere, Paris. The dynamic biological spectral work was discussed and compared with the electroencephalographic and, conversely, it was quite clear that his encephalographic work will pave the way for the entrance of the current behavioral studies of the dynamics of the neuroanatomical-neurophysiological system. An added historical treat was the opportunity to visit the laboratory of Charoot, and to spend a little time in his library.

8. P. Dejourns, Hospital Salepatriere, Paris. Work on the ventilation system and other system dynamics was compared. (Dr. Dejourns is one of a number of investigators - Gray, Grodins, Defares, Visser - to which the current dynamic systems analysis being developed would have greatest appeal).

9. D. Kerslake, Farnborough, England. Work on temperature regulation and seating was discussed and compared.

Yours truly,

S. Cardon, Vice President
GENERAL TECHNICAL SERVICES, INC.

HUMAN TEMPERATURE REGULATION - A 1964 MODEL

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Human thermoregulation has been from the following elements. A spectrum of sustained limit cycle oscillations of about 100, 400, 1400, and 12000 seconds is found in temperature, ventilation, and other system data.

The 100 sec. cycle is basic engine cycle and is the vehicle for heat production and its regulation. The cycle arises primarily in the skeletal muscles from unstable units, each unit consisting of several muscle cells and an oxygen supply capillary. The unstable unit would normally tend toward a maximum oxygen use rate, except that the oxygen supply is choked in a 100 sec. cycle of capillary opening and closing mediated by the vasodilative action of adrenaline. The open-close action of the capillaries circulate in local areas as a quasi-coordinated ring oscillator nonstationary signal with about 100 sec. periodicity. The heat pulses from these local ring oscillator systems account for heat pulses, oxygen consumption pulses, and ventilation pulses that appear. Other instabilities become involved in the same nonstationary 100 sec. cycle by non-linear synchronizing. The driving adrenaline level in the blood is probably regulated in a longer cycle coupled to a metabolic product.

The 400 sec. cycle is a hormonally mediated cycle arising from the hypothalamus. The action of the hypothalamus is to determine through the nervous system the relative blood flow through the major circulations, the skeletal muscles, skin, brain, internal organs, etc., by regularizing into a ring oscillator the conflicting flow demands among the various systems. An over-all blood flow 400 sec. cycle is regularized by a hormone (vasopressin) released into the blood through the hypothalamus-pituitary link.

The peripheral circulation in the major vehicle for surface temperature regulation and heat dissipation control. Deep body temperature is regulated by sensing the mean temperature of the mixed circulations at the hypothalamus, and controlling the relative flow to the peripheral circulation, the body "radiator". Reduced peripheral circulation prevents heat loss in the cold; increased peripheral flow provides for evaporative heat loss in the warm. The mean metabolism has only a small effect on temperature control. Thus, the 400 sec. blood flow cycle is the major vehicle for thermoregulation.

While similar hormonal mechanisms have been postulated for the longer cycles, they are not involved in the thermoregulation.

Abstract of Nov. 17, 1964 talk
in Proceedings of the 1964
17th Annual Conference on
Engineering in Medicine and
Biology.

Sponsored by

Office of Space Sciences
NASA Contract No. NASw-1066